Robots at War - Experiences in Iraq and Afghanistan

W.J. Smuda, L.Freiburger, S. Rogan, G. Gerhart
US Army, TARDEC Robotics Mobility Lab
Warren, MI, 48397-5000

ABSTRACT

Recent activities in Iraq and Afghanistan have shown the importance of robotic technology as a force multiplier and a tool for moving soldiers out of harms way. Early user involvement in innovative and aggressive development and acquisition strategies are the key to moving robotic and associated technology into the hands of the user. This paper updates activity associated with rapid development of the Omni-Directional Inspection System (ODIS) robot for under vehicle inspection and reports on our field experience with robotics in Iraq and Afghanistan.

ODIS physical security robots were used in check point inspections in Iraq and Afghanistan. The key technologies are Power, Omni-Directional Drive, RF Communications and Multiple computer systems. The key technical challenges were Power, RF scatter and reflection, Man-Machine Interface and software. The future tech developments will be support for mission packages, software engineering support and improved RF communications. We will discuss the Human Machine Interface, sensor configurations, demos to date, the value of Omni-Directional Vehicles for payload placement, reliability of the platform, and future work to simplify robotic system prototyping. The ODIS development efforts were funded by the OSD Joint Robotics Program (JRP).

1. Introduction

Up Front in Harms Way; the motto of the Joint Robotics Program.

1.1 Events leading to OIF/OEF Mission

In June of 2003, several simultaneous events began our journey. We briefed the ODIS under vehicle inspection robot at a Joint Robotics Program Working group, COL Bruce Jette, of the Rapid Equipping Force, was in the audience and CNN reported soldiers manning Traffic Control checkpoints as having the most dangerous job in Iraq. Snipers were actively targeting soldiers inspecting vehicles. Two soldiers were reported killed performing that mission while we were at the workshop.

After our briefing, COL Jette approached me and asked if we had taken ODIS to the field. I started describing our LOE at Ft. Leonard Wood, but COL Jette started laughing. I was somewhat taken aback until he explained the field is Iraq and Afghanistan. I immediately realized, as had COL Jette, the potential impact we could have by taking ODIS robot to theater. At that point we developed tunnel vision; the only thing we could see or think about was an ODIS robot deployment in 6 months.

1.2 ODIS

Figure 1 ODIS Robots at Baghdad Airport

For those not familiar with the ODIS robot, ODIS is short for the Omni-Directional Inspection System. The basic ODIS comes equipped with a visual camera and active lighting as the basic mission package (figure 1). ODIS can be thought of as a hovercraft on wheels. It can move forward or backward, left or right and rotate separately or in combination. This allows the operator to precisely position and maneuver ODIS while under a vehicle to view cavities, wheel wells and spaces above and around structural members. ODIS weighs in at about 40 pounds, is about 4 inches tall and 22 inches by 22 inches. It has been described as a pizza box on wheels or a large bathroom scale. ODIS provides a clear view of the underside of a vehicle. More importantly, ODIS robots provide standoff.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
00 DEC 2004	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Robots at War - Experiences in Iraq and Afghanistan	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **US Army, TARDEC Robotics Mobility Lab Warren, MI, 48397-5000**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM001736, Proceedings for the Army Science Conference (24th) Held on 29 November - 2 December 2005 in Orlando, Florida. , The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**8**	

Baghdad was not our first stop with ODIS. We spent a considerable amount of time with potential users, demonstrating and experimenting with ODIS, asking questions and listening to user comments. We conducted several major user experiments, most notably a Limited Objective Experiment with MP's and DOD guards at Ft. Leonard Wood, a demonstration project at the Port of Los Angeles and Port of Long Beach with the US Coast Guard, California Highway Patrol, Center for International Trade and Transportation and the Transportation Security Agency. Finally we provided the Chesapeake Sheriff an ODIS robot to support security at the Lee Malvo "Beltway Sniper" trial.

1.3 OCU

Figure 2 Wearable OCU

One outcome of all of our groundwork is the ODIS wearable Operator Control Unit (OCU) (Figure 2). Designed in-house and prototyped with the help of TRML Summer employees and co-op engineers, the popularity and acceptance of this OCU exceeded our wildest expectations. (Who says summer hires only get busy work?). The vest has pockets on the shoulders to accept antenna and video receivers, a pocket in the back to accept the OCU battery and a pocket in the front with a 7" color TFT screen. The vest has a tether to attach to a thigh mounted Joystick/Control box. The control box is designed so it can be used on either the right or left side. Once strapped on, the operator can let it go and it will be right there when it is needed again. This is a very important consideration when the user is armed with one or more weapons

The only mistake we made with this design was placement of the control box. When we originally designed it we were talking to folks stateside. All of the users we met carried their side arms on their hip. As soon as we got to Iraq, we noticed that side arms were most often carried on the thigh. For cases where a checkpoint operator carries a side arm, we were able to hang the control unit from the vest. Alternately, some soldiers preferred the thigh mounted control box and switched to a sling carrier for their side arms.

We have received many compliments from users in the field, both for ease of use and functionality. Kudos to all who worked on this part of the project!

1.4 Power

Another lesson we learned from our users is to pay attention to power issues. If you were to ask today, what the 4 most important issues faced by small robot designers are, we would have to respond that they are power, power, power and comms. Of course the fourth can usually be solved by solving any of the first three.

Small robot power is synonymous with batteries. Our users indicated that if a battery went bad and a replacement couldn't be found, we might as well keep the robots in the lab. The corollary includes chargers. The ODIS T1 prototype had a "sweet" battery pack. The users were impressed with how easily and quickly a battery pack could be swapped out. Unfortunately, the battery pack was hand made and the charging system, although extremely functional, resembled a mad scientist's workbench.

For the ODIS T2, we switched to SINCGARS radio batteries. This is a robust battery pack that is already in the inventory. We settled on the rechargeable Nickel Metal Hydride BB-390 for both the robot and the OCU. We had originally hoped to use the new rechargeable Lithium Ion batteries, due to higher power density and lower weight, but the current requirements of the robot caused premature battery failure.

The BB-390 proved to be an excellent choice; we over packed 3 BB-390 batteries with each robot.

When we began operating in Baghdad, we observed an op tempo we had not experienced stateside. The checkpoint operators wanted to operate 24x7, so they found additional BB-390 batteries within a day. We also took this as an affirmation of the soldier's acceptance. In the words of a senior NCO, "They must like that robot, or they would never have even bothered looking for additional batteries."

Finally, we over packed a battery charger with each ODIS. The charger was capable of operating from 12 volt power from a Suburban, 24 volt power from a HMMWV, 120 volt AC from a generator or 240 volt Iraqi power. Before we left, we observed the chargers being used in each configuration. The chargers are capable of charging 2 BB-390 batteries simultaneously.

2. OIF/OEF

When we arrived in Baghdad, we had to work our way up the chain convincing people as we went along, that we had a useful tool and we were not going to waste soldier's time. We finally were invited to brief the Force Protection Council at the former Presidential Palace (now Coalition HQ). Rather then do a Power Point presentation, we simply set ODIS on the conference room table and ran it. We were tasked to begin deployment at the checkpoints the next morning.

A big point in our favor was ease of use. We estimated that we could train soldiers in a day. In fact it took much less time. After 2 hours, the first soldiers we trained in Baghdad were taking the robots to their checkpoints. One soldier was heard to remark, as he was loading his ODIS in a HMMWV, "I can't wait to get out to the checkpoint!" Then with a puzzled look on his face, he said, "Wow, I never thought I would be saying that."

Figure 3 Car Bombing - Before and After

Checkpoints are dangerous places. At least four of the five checkpoints we worked at in Baghdad have had major incidents since we left. All of the incidents happened just outside of or right at the entry to the checkpoints. The 14th of July Bridge is an example (Figure 3). The photo on the left is a picture taken during our mission, the picture on the right is a news photos from the opposite vantage point.

Look at the placement of the soldier in the picture on the left. The blast occurred where the black car is behind the delivery truck. The bridge is a very good location for a controlled access point, but there has to be an edge. We need to put robots where that soldier was on 17 March. An additional threat to soldiers on the line is snipers. Soldiers on the line know that something can happen at any time. Standoff is the only remedy.

2.1 Checkpoint Operations

There are basically two ways to run checkpoint operations. Ad Hoc, where a patrol closes a road or intersection or fixed locations, as we encountered at the entrance to the Green Zone in Baghdad

Figure 4 Ad Hoc Checkpoint at the Kandahar Bazaar

In Kandahar, the checkpoints were typically Ad Hoc. The patrol had an event of interest they need to control (Figure 4). The event we experienced was the entrance to a Bazaar. The Bazaar is like a fair,

the merchants arrive early to set up, and the customers (coalition forces for this one) arrive several hours later.

In Baghdad, we worked at several very different checkpoints. Physical locations ranged from on a levy to on a bridge, paralleling a busy street to under an overpass to well back from an intersection. In the picture shown in Figure 5, a soldier is operating the ODIS robot from about 75 meters away, while under cover in a concrete revetment with a 4 foot dirt wall in front of him. ODIS is under the blue vehicle in the distance.

Figure 5 Soldier Operating ODIS with Standoff

We were surprised at the condition of some vehicles. There were many older vehicles some in pretty rough shape. We observed several vehicles that apparently no longer had functional springs. The clearance was as low as 4 inches (Figure 6). It was amazing to watch them grind over speed bumps. The ODIS robot had a video antenna mounted on the top. We moved the antennas to the front payload bay and ODIS to keep them from getting destroyed by low hanging car parts.

Figure 6 ODIS Under Iraqi Civilian Vehicle

2.2 Environment

One of the things we are most often asked is "How was it over there?" This can be answered in a lot of ways, but mostly folks have this picture of Iraq as a hot dusty place with camels and tanks running side by side. While we were there, the weather was temperate. The first few nights in February were chilly; we had to wear our field jackets and the heat was on in the tent. By the time March rolled around, the weather was mostly pleasant, on a few days the temperature lingered around 100 F, but the following week, temperatures were back in the 70's. In April, we experienced mostly temperatures in the 80's and 90's. It rained once while we were in Iraq. The distance between raindrops splattered on dusty windshields could be measured in inches.

Figure 7 Dust being Kicked Up by a Passing Vehicle at Camp Anaconda

Dust is everywhere. It gets into everything, but it's not as bad as I expected. It's more like living on a dirt road. But, since the pavement seems to be only a suggestion, almost everywhere we lived was like living on a dirt road. To mitigate the dust problem, almost every surface that can be walked or driven on is covered with gravel. Gravel is better than dust, but it gets hard to walk on after awhile.

It rained for a few days when we were at Bagram AB north of Kabul in Afghanistan. One night it rained heavily. Bagram itself is at about 7000 ft. The Airbase is in a valley ringed by mountains reaching to about 12000 ft. The morning after the rain we awoke to a panorama of snow capped mountains.

2.3 Roads

Baghdad is a very large city, and as such it has a large city center with high population density. Downtown Baghdad has many high-rise housing buildings. It also has many parks and sculptures.

The picture below (Figure 8) is downtown Baghdad. Wide boulevards and are flanked by government buildings and parkways.

Figure 8 Downtown Baghdad

The roads in Iraq and Afghanistan could not be more different. I knew beforehand that Iraq was, at one time, a very western country, but I was still surprised at the quality of the roads. True, many guard rails did need maintenance, the shoulders were packed with litter and there were pools of oil in the ditches near fuel points, but they were relatively smooth and well marked. This is a good thing, since we mostly convoyed in Suburbans at speeds well above 100 mph.

The picture in Figure 9 is of the highway between downtown Baghdad and the Baghdad International Airport. This is about halfway to Baghdad, looking toward Baghdad. Although this is Friday, about noon, you will notice that there is no traffic. Normally there is an incredible amount of traffic. This road has been dubbed "The most dangerous 5 miles of Highway in the world" by CNN.

This picture was taken on April 9, 2004.We were convoying into Baghdad, when we began to encounter a larger than normal number of vehicles driving the wrong way on our side of the freeway. A short while down the road, were stopped by security forces and informed that an incident was under way ahead and we should turn back. We assumed an IED.

Figure 9 Baghdad Airport Freeway

When we returned to Camp Victory, we could see thick black smoke roiling up from the vicinity of the incident. We found out later that a convoy had been attacked, a fuel tanker was burning and a driver had been taken hostage. Fortunately, his captors let down their guard about a month later and he escaped to safety. Had we left 5 minutes earlier, and we would have been in the middle of this incident.

Figure 10 Typical Afghan Road

Since I had no real preconceived notions, Afghanistan roads were also better than what I expected. A major highway was a two lane asphalt road. I expected more hard dirt tracks, probably because that is what I see on the news. We did not spend much time off the airbases in Afghanistan. In Kandahar, we were able to leave the base to observe checkpoint operations near the Bazaar site (Figure 10).

The security team created an Ad Hoc checkpoint by parking a Bradley and closing the road. Merchants were allowed into the checkpoint in groups of about 10 vehicles. The passengers exited the vehicles and stoically moved to the far side of the road where they waited patiently for the MP's to visually check the vehicles and let the dogs search. Occasionally, one of the merchants would be randomly chosen to completely unload his cargo. I say his, because all merchants were men or boys. In the time we were in Afghanistan, I did not see a single Afghan woman.

Similarly, the entrance to Bagram AB is also a two lane road (Figure 10). The roadway is made narrower by jersey barricades. In the distance, two checkpoint operators are inspecting a truck with a mirror. When we left, they were making plans to lay a concrete pad at that point for under vehicle inspection with ODIS.

As much as we would have liked to, we did not stray very far from the marked paths in Bagram. Everywhere you look, in the PX, in the Dinning Facilities, the movie and telephone rooms, you find mine identification displays and warnings. Afghanistan is a heavily mined country. I have heard estimates of 10 million unmarked mines. There are old, unmarked minefields flanking the road approaching Bagram.

Figure 11 Main Entrance to Bagram Air Base

There is a mine victim's aid station at the main entrance to the airbase. It is heavily used. We were told that at least once a week children are brought in with missing limbs. While we were at the gate, there was a group of about 12 children playing just across the wire. Three were missing limbs.

There are minefields all around the perimeter of the base. This was a Russian base, then a Taliban base, and now coalition forces. Perimeter guards have been issued paintball guns to shoot at children who stray into off limits areas. This is to let their parents know they have been playing dangerous games.

The number of mines in Afghanistan is mind boggling. Mine clearing is a difficult and dangerous job. Detecting, marking and clearing mines is an obvious mission for robots. Several robots are in use for this task, but they are large, expensive and scarce.

2.4 Communications

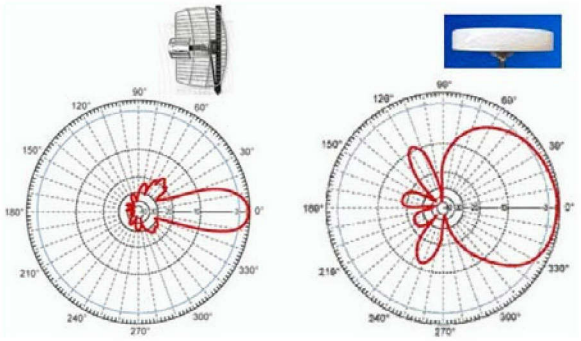
Communication issues in Iraq turned out to be an obstacle. The original design allowed the operator approximately 75-100 m standoff in an open area scenario. This was accomplished with a 3 dB omni-directional antenna with an SMA connector on the receiver end. Ground robotic systems typically use the 2.4 GHz ISM or IEEE 802.11b/g bands for video communications. Rubber ducky or patch antenna configurations are commonly used. Although this frequency spectrum has many benefits, they simply fall short. These antennas don't give the operator adequate stand-off to stay clear of the blast radius or within a sniper's scope. Several antennas were tested in order to address problems of range (stand-off), noise, and RF scatter.

Figure 12 Checkpoint Barriers

In each direction blast barriers protect personnel areas such as mess hall, barracks, and checkpoints. Whether the threat may be an incoming mortar round, or a twenty-five pound car bomb, these barriers serve as layers of protection. Figure 12 shows a typical checkpoint scenario. A problem arises when radio frequencies get mixed into the battlefield. The RF fields have to penetrate many layers of sand, cement,

and metal. Each of the external factors that convolute the RF path has subsequent results on the data quality, primarily the video, which has the higher bandwidth requirements

The controls for ODIS are typically worn by the operator on a vest. The assembly is flexible, but should only be used in an ad-hoc situation when the luxuries of a bunker or HMMWV setup are unviable. Directional antenna size constraints require the operator to permanently mount them and rearrange the control components for convenient use (i.e. not worn on the body, but maybe laid on some surface near the mounted video receiver antenna). Panel, Yagi, and reflector grid antennas were tested in a variety of scenarios. Figure 13 shows the radiation pattern for the two antennas selected--1) fixed locations (Figure 13 a), and 2) ad-hoc situations (Figure 13 b).



(a) (b)

Figure 13 ODIS Antenna Radiation Patterns: (a) Grid Antenna, (b) Patch Antenna

The reflector grid antennas performed the best (Figure 13 a). This 15 dBi reflector grid antenna with a 16 deg. horizontal beam width was selected based on its combination of performance and size. Figure 14 show the highlights of each antenna. With a range of 300+ m, it allows a significant increase in standoff, which, combined with existing measures such as concrete barriers, can give the operator complete isolation from checkpoint threats (i.e. noise, RF scatter). The other antennas experienced severe signal degradation after 250 m.

	Patch (omni)	Grid (directional)
Range	75-100 m	300+ m
Gain	3-5 dBi	16 dBi
Horizontal Beam Width	70 °	16 °
Connector	SMA	N-type

Figure 14 ODIS Antenna Specifications

The antennas were tested in fixed positions and on the move. After 200m, optimal picture quality is obtained when the robot is sitting still. The grid antennas still displayed a viewable picture at this distance, maintaining the preferred sweeping inspection capability. The corridor testing did not completely simulate the high barriers actually used in Iraq, but the signal strength behavior observed during testing showed promising results. The results of the antenna study encouraged the October 2004 theatre deployment of 20 antennas to Iraq, Afghanistan, and U.S. locations.

3. Ongoing Research

As we entered into the ODIS project, soon after 9/11 we consciously adopted a spiral development process. We knew we were breaking new ground and the only way to success was to involve the user. Based on our wearable OCU and our battery strategy, I think we are doing a pretty good job. The next turn of the spiral will involve mission packages.

3.1 -Near Term Enhancements -Clearing Station 1

Most checkpoint operations are conducted in stages, with the first station being initial contact and therefore the most dangerous. There are usually several soldiers and interpreters in this area. They have to perform the first contact actions, have occupants leave vehicle, look inside for suspicious objects and inspect under a vehicle. ODIS has the capability to at least remove one person, the under vehicle inspector. We believe ODIS can be outfitted to do more.

In order to clear the first station of a checkpoint, we need to be able to communicate with the vehicles driver and occupants, look into the vehicle passenger compartment, trunk and under the hood. This will give the checkpoint operators a first screening to help them determine the risk level of the vehicle. Two low cost enhancements for ODIS are under development and can be available this fall.

The first is two way audio. Using a simple web based translator operating on a PDA, developed by Exponent, checkpoint operators can sent voice commands in the local language, to the vehicles driver and occupants. Commands are selected from a menu on the PDA. Phrases might include:

Stop engine
Show ID to robot
Stop or we will shoot
Open all doors and bonnets
Move to waiting area
Remove package from trunk

Figure 15 Zipper Mast

The second is a low cost, low profile camera mast. Space technology has provided us with a device that dispenses three rolls of spring steel to create light weight structural elements for space station construction. This same technology can be used to create retractable rigid vertical triangular beams from a dispenser no taller than the payload bay on ODIS. A larger version is used by the border patrol to deploy mobile cameras and lights (Figure 15). In the photo, one is extended fully; the other is only partially extended. The camera mast will give checkpoint operators the ability to peer into a vehicle. It will also allow the camera to be elevated while under large trucks, giving inspectors an additional degree of freedom for their inspection.

3.2 The Future

There is a lot we can do to accelerate moving robotic technology into the hands of the soldier in the field. Within a year, we expect to have an alternative, lighter less expensive robot available. The UVIS or Under Vehicle Inspection system is being developed via a Phase 2 SBIR program (Figure 16). The UVIS is expected to weigh in at about 15 pounds. Mobility can be adjusted by changing tires, with a height trade off.

Figure 16 ODIS and UVIS

Chemical detection is another hot topic for inspection robots. In an attempt to lower inspection cost, we expect to have a simple wand that can be used to swipe handles, trunk lids, bumpers etc. with a cloth pad that can be brought back and analyzed.

In reality, ODIS is a mobility platform. It can carry a variety of payloads. It is a low cost platform, which means we can procure many of them. Future versions will be able to swap the low profile wheels for rough terrain wheels. Mine clearing operations are a future research goal.

4. Conclusions

Our first mission was a success. Unmanned Ground Vehicles are a force multiplier and also move soldiers out of harms way. We had the opportunity to also talk with EOD soldiers who have many years of experience with robots to deal with bombs, IED's and UXO. We learned from each other.

The IED taskforce is doing great things with robotics in the EOD arena. We are making inroads into Force Protection with ODIS. We have had requests for additional ODIS robots in Iraq. We will be taking additional robots over in the near future.